# Sub-to-Supercritical Mixing in Single and Dual Species Systems

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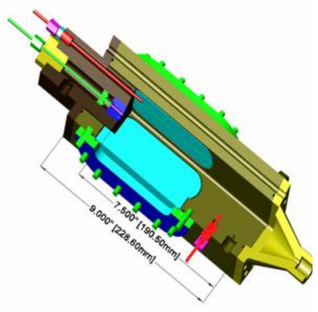
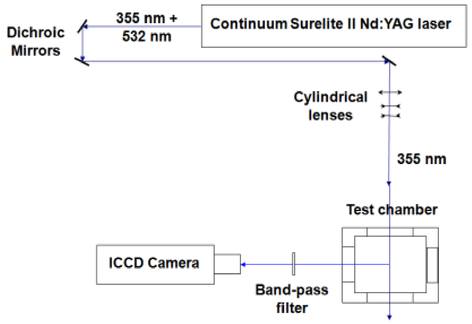
## ABSTRACT

Subcritical and supercritical fluid injection into a quiescent atmosphere comprising single and dual species was investigated. Density distribution was measured and density gradient profiles were inferred from experimental data. A novel method was applied for the detection of detailed structures throughout the entire jet center plane. A linear stability analysis for supercritical cases, which has not yet been solved earlier by researchers, was found through an asymptotic solution of the dispersion equation for very high Weber numbers.

## EXPERIMENTAL SETUP



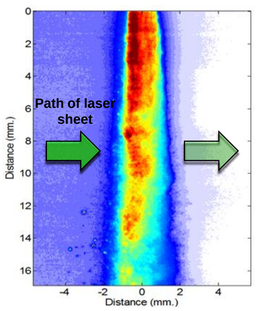

HIGH PRESSURE CHAMBER



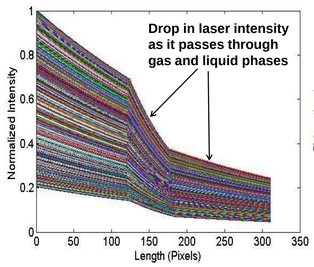

SCHEMATIC OF APPARATUS

Planar Laser Induced Fluorescence is used as the optical diagnostic technique. Fluoroketone is used as the test substance due to its low critical point and good spectroscopic properties. The laser beam is formed into a 0.1 mm × 25 mm sheet and is made to strike the jet center plane. Images acquired by the ICCD Camera at 10 Hz are then analyzed to determine the density and core lengths.

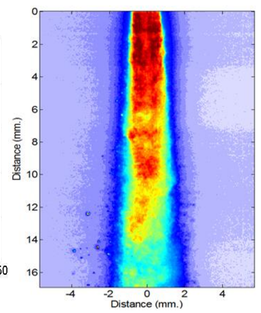
## LASER CORRECTION




UNCORRECTED IMAGE




LASER INTENSITY DROP

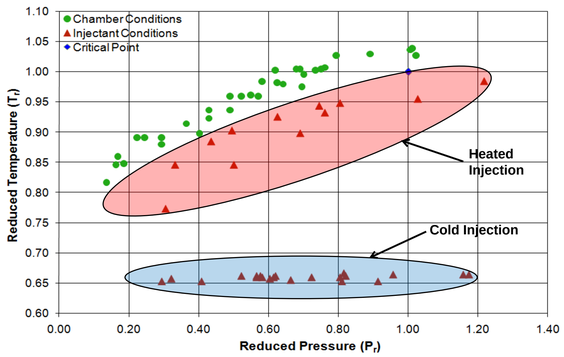



CORRECTED IMAGE

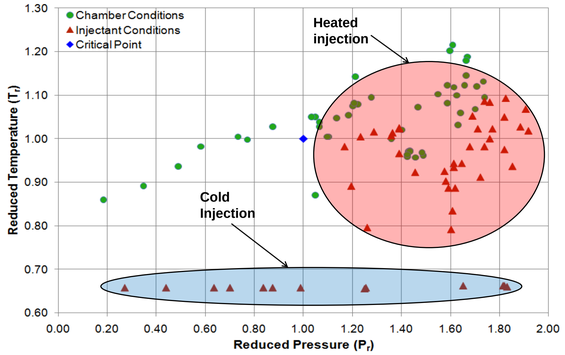
A non-linear fluorescence theory was developed to account for the loss of laser intensity while passing through the liquid and vapor phases separately. Fluorescence $S$ at any point $(p_x, p_y)$ for laser intensity $I$, density $\rho$, fluorescence yield $\varphi$, absorption cross section $\sigma$ and distance $x$ was derived as:

$$S(p_x, p_y) = F\rho\varphi\left[1 - e^{-I(0,y)\left(\frac{\lambda}{hc}\right)\sigma e^{-\sigma\eta x}}\right]$$

## EXPERIMENTAL CONDITIONS

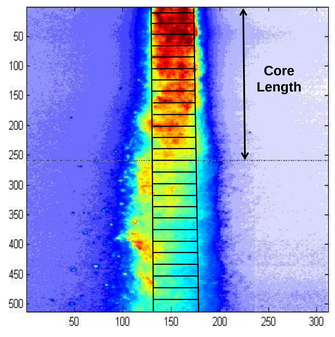



TEST MATRIX FOR SINGLE SPECIES INJECTION

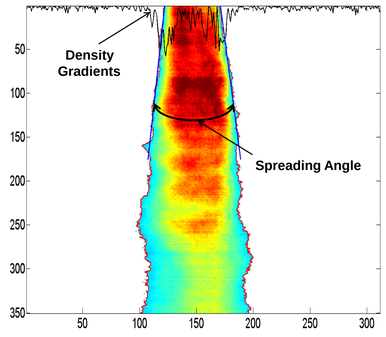



TEST MATRIX FOR DUAL SPECIES INJECTION

## CORE LENGTH AND SPREADING ANGLE




CORE LENGTH MEASUREMENT



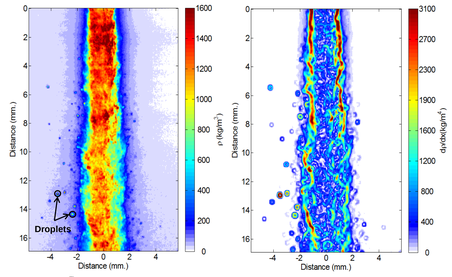

SPREADING ANGLE CALCULATION

Core length is defined as the intact section of the jet, measured along its axial length, beyond which a significant change of density occurs. The method used to determine the core length divides the image into smaller matrices along the axis of the jet, and then uses their eigenvalues to compute various points of inflexion along the jet. The core length is finally determined by comparing the local densities at these inflexion points and selecting the length at the region of highest density change. The jet spreading angle has also been found out as shown in the figure. These quantities have been plotted against the chamber to injectant density ratio for single and dual species mixing and trends were studied.

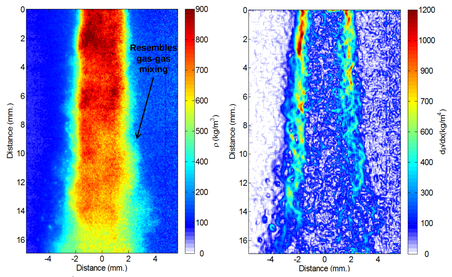
## RESULTS

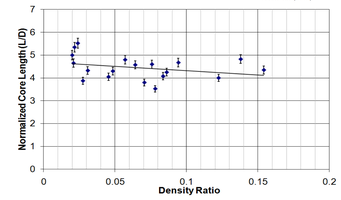
### SINGLE SPECIES INJECTION

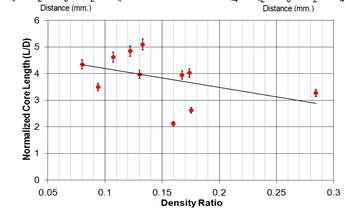
SUBCRITICAL INJECTION

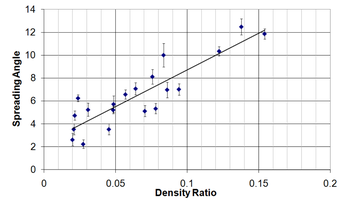


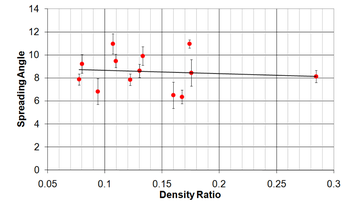

SUPERCRITICAL INJECTION



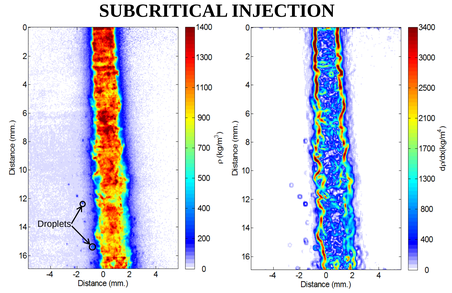



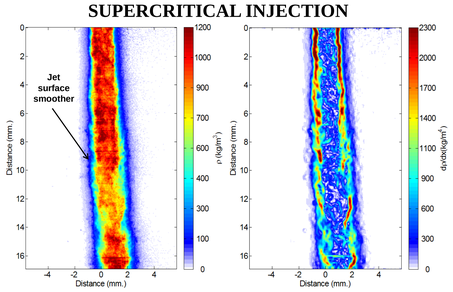



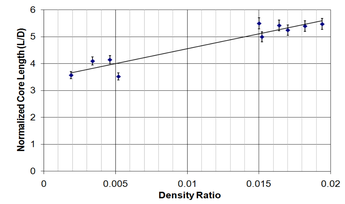

### DUAL SPECIES INJECTION

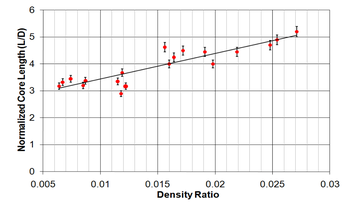
SUBCRITICAL INJECTION




SUPERCRITICAL INJECTION




## CONCLUSIONS

For a jet injected into a subcritical environment, surface tension and inertia forces dominated the jet breakup process, and droplet formation was observed, while for supercritical injection the jet became smoother and both droplet formation and irregularly shaped material were observed when a portion of the jet broke off. Differences in the variation of core length and spreading angle against density ratio have been found for single and dual species mixing. An increase in the jet divergence angle for single over dual species indicated higher diffusion and thus enhanced mixing.